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Investigating what students learnt about biodiversity following a visit to a nature reserve using Personal Meaning Maps

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ABSTRACT

We investigated what students learnt about biodiversity, a broad and multi-dimensional concept, challenging to understand, following a visit to a nature reserve. Acknowledging the individual nature of informal learning, we explore Personal Meaning Maps (PMMs) coupled with semi-structured interviews to investigate learning among 13 scouts aged 13–15 years as they participated in a single guided tour to a nature reserve in Mauritius. PMMs were analysed both qualitatively and quantitatively. Adopting a constructivist approach, biodiversity learning was framed along three lenses, namely, 'ecological literacy', 'biodiversity and society' and 'nature and self', recognising that biodiversity is a socio-scientific concept. Following the visit, there was an increase in ecological literacy through an understanding of the importance of biodiversity, conservation measures and endemic species. Participants retained a species-centred view of biodiversity. Students could better critique biodiversity and society issues and displayed a higher appreciation for nature and the intrinsic value of biodiversity. The visit contributed to an enrichment in biodiversity-related vocabulary especially regarding local endemic and extinct species. Prior knowledge determined vocabulary enrichment but not conceptual additions among individual students. We suggest a wider explo ration of PMMs to investigate prior knowledge and subsequent learning during nature reserve visits which can powerfully enhance biodiversity education.

KEYWORDS

Biodiversity learning; Personal Meaning Maps; nature reserves; informal learning; Mauritius

Introduction

'What' students learn about biodiversity during a guided tour to a nature reserve might have a range of potential answers. 'Biodiversity' implies ecological, social and economic concerns (Navarro-Perez and Tidball 2012). As asserted by Kilinc et al. (2013), an understanding of the concept means a consideration of the importance of biodiversity as well as why and how its loss could be curtailed for the sustainability of our planet. Nevertheless, biodiversity has been described as a complex socio-scientific concept that does not easily transfer to people's minds, especially for adolescents (Van Weelie and Wals 2002). Educational programmes of nature reserves are often designed to enhance connection with nature, promote biodiversity literacy and pro-conservation behaviours which are crucial for the success of biodiversity conservation (Burnett et al. 2016). These programmes present biodiversity in authentic contexts and often provide informal learning opportunities for young people during their leisure activities, far from the influence of schools. Informal learning is characterised by being free-choice and learner driven (Falk 2005), focusing on instilling delight, interest, and curiosity such that the learning experience takes the forefront. Thus, learners are likely to choose where to focus their attention based on individual preferences, prior knowledge and beliefs which determine what

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they might learn. Faced with an increasing need to attract funding for conservation education programmes, practitioners are under pressure to demonstrate that learning does occur and that biodiversity loss is curtailed (Ardoin et al. 2020). Despite the large body of literature on environmental programme evaluation in developed countries (Brügger, Kaiser, and Roczen 2011; Kossack and Bogner 2012), there are comparatively fewer studies in developing countries including Mauritius (Burnett et al. 2016).

The entry level knowledge of biodiversity of individual visitors cannot be pre-determined and one cannot predict how much a student would learn during a visit of a purely informal nature. Therefore, investigation of learning during guided tours warrants data collection tools that capture the individual nature of learning based on students' individual preferences, prior knowledge, and beliefs. In this article, we explore PMMs and semi-structured interviews to investigate biodiversity learning. The research question is 'What do students learn about biodiversity during a guided tour to a nature reserve as part of their leisure activities?'. We framed our analysis of biodiversity learning through three lenses namely 'ecological literacy', 'biodiversity and society' and 'nature and self'. This study is derived from a study aimed at investigating situational interest and learning about biodiversity (Kamudu 2021).

Literature review

Importance of understanding the concept of biodiversity

The Convention on Biodiversity defines biodiversity as '*the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*'. (United Nations 1992). This definition implies diversity at all levels, from genes, species, populations, communities and can encompass the evolutionary, ecological, and cultural processes that sustain life. A rich biological diversity is essential for the fundamental processes that sustain life such as capturing biological resources, producing biomass, regulating climate, and maintaining the nutrient cycle. Biodiversity is also intricately linked to sustainability issues since it fulfils socio-economic needs through ecosystem services such as food, medicines, etc. Even though biodiversity provides for most of society's fundamental needs, human actions threaten more species with global extinction now, more than ever before such that biodiversity loss is a worldwide concern (Redford et al. 2012). A failure to understand the intricacies of biodiversity and ecosystem functioning by society might have contributed to human-induced species loss and ecosystem degradation, accentuated by anthropocentric activities such as overexploitation and the introduction of Invasive Alien Species. Today, the conservation of biodiversity is of prime importance, yet, diverging agendas from NGOs, politicians, regulatory authorities, and scientists might lead to conservation challenges (Florens 2013). Thus, biodiversity is a complex topic with closely knit ties between science, society, politics, and economics.

Halting the loss of biodiversity calls for enhanced biodiversity education and developing responsible citizenship especially among young people (Kilinc et al. 2013). However, students face the challenge of understanding biodiversity, which is a multi-dimensional and complex concept, failing to make the connection between its ecological, economic, and social significance (Menzel and Bögeholz 2009). In parallel, it becomes equally challenging to investigate students' understanding of the term 'biodiversity'. We thus explored biodiversity learning by considering their knowledge of the scientific aspects of biodiversity, how they relate the concept with society and the extent to which they are individually connected with nature.

Approaching biodiversity learning through three lenses

The most common difficulty that students face is the inability to define the concept of biodiversity as they often adopt a species-centred view and tend to overlook ecosystem and genetic diversity (Yorek et al. 2008). However, a thorough understanding of ecosystem functioning, e.g. food webs interactions and ecosystem services, provisioning of food and materials, temperature regulation, clean air, recreation, and cultural services, might help students grasp the significance of species loss. An appreciation of the intrinsic value of biodiversity helps young people develop nature connectedness (Liefländer et al. 2015) and appreciation for environmental protection (Kaiser et al. 2014). Such emotional engagement during learning where knowledge blends with values has been termed as the 'nature and self' perspective (Van Weelie and Wals 2002). Furthermore, human activities and policies have continually impacted biological resources, such that biodiversity is intricately linked to societal issues. The historical resource depletion, habitat destruction, and the introduction of invasive alien species have changed ecosystem dynamics in several countries, leading to significant biodiversity loss (Florens 2013). The extinction of the dodo in Mauritius is a flagrant example of human induced extinction. Thus, biodiversity also has social and economic implications. Another example in Mauritius is the socio-scientific debate around the authorisation from government for mass culling of the endemic flying fox of Mauritius to protect farmers' interest, a decision vehemently condemned by the scientific community (Florens 2016). Thus, biodiversity issues enable students to reflect on relevant, controversial, emotionally charged and socio-scientific topics. An investigation of biodiversity learning among young people could also consider how they link ecological knowledge with socio-economic issues. We therefore framed our investigation of what students learnt about biodiversity through three lenses: (i) an ecological literacy lens, (ii) a biodiversity and society lens and (iii) a nature and self-lens (Van Weelie and Wals 2002).

Biodiversity is an example of what Rennie and Stocklmayer (2003) describe as the 'public do not understand science on science's terms but on their terms'. Learning about biodiversity helps students to understand plurality of viewpoints, analyse different meanings and dimensions, and develop critical thinking about conservation (Navarro-Perez and Tidball 2012), guided by values and empirical evidence (Pedretti and Nazir 2011). Participation in environmental education programmes often leads to knowledge retention (Kuhar et al. 2010), pro-conservation behaviours and opinions (Burnett et al. 2016) and connectedness with nature (Kossack and Bogner 2012). A trip to a nature reserve enables students to have an authentic experience of biodiversity and its conservation *in situ* where informal learning occurs in the actual world (Braund and Reiss 2006). Acknowledging the differences in prior knowledge and knowledge gained among different individuals based on their personal and social context (Falk and Dierking 2013), researchers might face methodological challenges on investigating the individual nature of learning.

Personal Meaning Maps

Many studies have used pre-post questionnaires to document the impact of environmental education programmes (e.g. Kossack and Bogner 2012) which might limit how students express their understanding of concepts during informal education programmes (Lelliott and Rollnick 2010). A promising tool is Personal Meaning Maps (PMMs), a variant of concept maps, first proposed by Falk (2003) to investigate the meaning-making process during informal learning. The basis of PMMs is that it captures how a visitor conceptually organises ideas about a topic before and after an informal learning intervention and therefore considers prior knowledge. PMMs have had wide use in assessing programme impacts (Faria, Boaventura, and Guilherme 2019; Van Winkle and Falk 2015). Most of these studies have coupled the PMMs with interview techniques which we adopt in this study.

The study was theoretically framed through a constructivist framework considering that meaningful learning occurs whereby the learners integrate new information into their existing knowledge structures (Novak 2002). Thus, learning during the guided tour is dependent on the individual's prior knowledge.

Methodology

Participants and site description

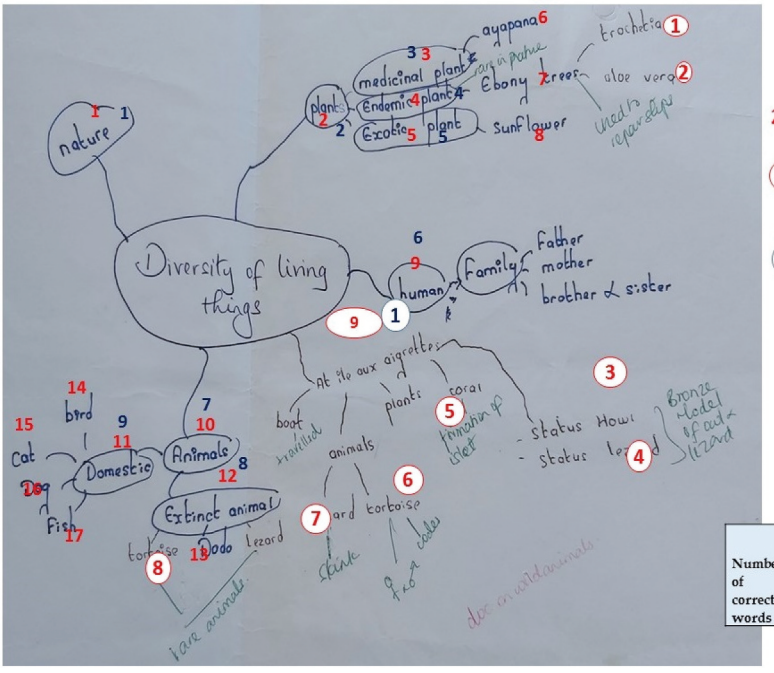
This qualitative case study examined a group of 13 students (aged 13–15 years) who participated in a single guided tour to Ile aux Aigrettes (IAA) nature reserve, during a scout outing. Ethical clearance was obtained from the university. IAA is an offshore islet situated about 800 m off the south-eastern coast of Mauritius. During the 1h30minutes tour provided by the Mauritian Wildlife Foundation (MWF), the group walked along a pre-determined trail of about 1.5 km. The trail includes stopping points at specific locations where the guide stops to elaborate on biodiversity and conservation-related information with respect to the attractions. Participants encountered the following attractions: (i) endemic plants (including the ebony tree), (ii) endemic animals (e.g. Pink Pigeon, Mauritian Fody, Telfair Skink, endemic Geckos and endemic Bats), (iii) life-size bronze models of extinct animals (e.g. saddle-back tortoise, dodo, giant skink, the extinct owl), (iv) endemic plant nursery and (v) Aldabra tortoises introduced on the islet as analogue species to perform the ecological role of the extinct tortoise. There is also small museum/gift shop where models, skeletons, photographs/paintings of extinct animals are displayed. The main biodiversity-related concepts explained by the guide are (i) a brief introduction to concepts such as endemic, extinct, native and ecosystem; (ii) life history of tortoises; (ii) causes of extinction; (iii) historical overexploitation of plants and animals leading to forest degradation and extinction; (iv) conservation work such as supplementary feeding, tagging of animals, re-introduction, hardening of plants and translocation; (v) heterophylly among endemic plants with prominent red mid-ribs in younger leaves but not in older leaves which is an adaptation against grazing by tortoises; (vi) evolutionary adaptions, e.g. the atrophied wings of the extinct dodo, a flightless bird which could run fast; (vii) feeding relationships; and (viii) ecological roles of animals as dispersers and pollinators. Since the exhibits are not accompanied by labels, visitors rely heavily on the guide to provide information. During this tour, the guide played what Randall and Rollins (2009) described as a leadership and mediator role, setting the pace, ensuring the tour was completed on time and maintaining group cohesion. The guide elaborated on a pre-defined script to explain the exhibits and sometimes attempted to engage with students through questioning. The students observed and listened carefully, occasionally answered the guide and conversed among themselves, without taking written notes.

Data collection

The data collection process outlined below, followed suggestions from Lelliott (2009).

Step 1: Drawing of PMMs by participants. Students were first taught how to draw PMMs using a central phrase 'school' which is unrelated to the study. A week prior to the visit, students drew their respective PMMs around the central phrase 'diversity of living things' in blue ink. They were free to write their ideas and were informed that there were no right or wrong answers. A student's PMM is shown in Figure 1.

Step 2: Probing for information. The interviewer requested clarifications from the students regarding their respective PMMs, making notes in red ink. In the PMM, the student wrote 'tortoise' and 'lezard' branching from animals which in turn branches from 'ile aux aigrettes'.



Number of correct words	Before	17	Number of appropriate concepts	Before	9
	After	26		After	10
	New	9		New	1

Figure 1. An example of a PMM from the student Owen, illustrating how words and concepts were counted.

The probing questions asked '*Why did you write this*?'. The student's reply was '*On IAA there were male and female tortoises and the brown lizard we saw. These are part of diversity of living things*'.

Step 3: Semi-structured interviews. A semi-structured interview had questions exploring students' understanding of the term biodiversity, its importance, threats and conservation measures, biodiversity, and societal issues as well as the students' appreciation, involvement and views about biodiversity. This exercise was meant to investigate students' prior knowledge of biodiversity.

Step 4. The visit to IAA. Extensive field observation was conducted during the visit taking field notes according to Cox-Petersen et al. (2003), recording each type of activity involving students (e.g. exhibits), the time spent at each stopping point, students' behaviours such as capturing photographs and interactions with the guide. The whole guided tour was audio-recorded which captured the content of the guide's exposé and conversations with participants.

Step 5. A revision of the drawn PMMs. A week after the visit, students made additions on their original PMMs in black ink. The interviewer made notes in green ink during probing.

Step 6: Post-visit interview. The same semi-structured interview questions were used to investigate any change in knowledge of biodiversity.

The semi-structured interviews and probing utterances using PMMs were audio recorded and transcribed.

Data analysis

The PMMs and interview transcripts were uploaded on Atlas TI software and inductively derived codes were grouped into emerging themes falling within each of the three lenses of what students learnt about biodiversity. The PMM being highly individual in nature, there is no expectation of similarity among different PMMs and no correct answers (Falk 2003). Thus, we first conducted an

inductive content analysis of the PMMs and interview transcripts of each student before and after the visit and then compared answers across students for different aspects of the three lenses. Second, the PMMs were quantitatively analysed, espousing the suggestions of Falk (2003) by counting the change in the number of correct words (vocabulary enrichment) and concepts related to biodiversity. Vocabulary enrichment represents an expansion of comprehension through words that tie ideas and concepts together (Rupley et al. 2012). Plants, dogs, leaves, humans, bats, reproduction, eggs, feeding, seeds and common names of plants and animals were regarded as correct words since they represent different aspects of living things. A concept is a word/phrase representing a scientific idea illustrated by words having a shared meaning (Novak and Canas 2008). Conceptual addition would represent an improvement in how the student organised scientific information in his/her knowledge structure. To ensure rigour, written words were regarded as a concept only if they represent a scientific idea, for example, 'endemic'. Examples of concepts (e.g. sugarcane is a plant), were disregarded. Repeated words and concepts were counted only once. An example of a PMM from the student Owen and how words and concepts were counted is shown in Figure 1. To ensure reliability and validity, the coding of both the PMMs and interviews was conducted independently by the first author and a biology educator. The inter-rater coding and analysis reached a full consensus.

Results

What did the students learn about biodiversity?

Everyone entered and left the guided tour with different depth of knowledge of biodiversity. For ease of comparison, we classified students' knowledge into three groups based on their answers relative to one another before and after the visit: knowledge score 1 is the lowest level of knowledge and score 2 is better than score 1 and knowledge score 3 is the highest or deepest level of knowledge and understanding demonstrated by participants.

Ecological literacy lens

Most students had a species-centred view of biodiversity before and after the visit. However, for the majority, there was a deepening of students' understanding of the importance of biodiversity, endemic and extinct species, and awareness of examples of conservation practices. The result is presented in Table 1.

Before the visit, students described the concept of biodiversity as the variability among plants and animals, including humans. All students mentioned exotic and medicinal plants, domestic and wild animals on their PMMs. Following the visit, there were additions of endemic plants and animals including extinct animals. Students also described diversity according to differences among organisms such as feeding habits or body shapes (eight students) and characteristics of animals (four students). After the visit, participants who recognised ecosystem diversity increased from four to seven with mentions of forests in cold and tropical regions. The results indicate that most students restricted their conception of biodiversity at species level, understanding variability across species with less recognition of ecosystem diversity. Genetic diversity was overlooked.

Prior to the visit, students described plants in terms of their ecosystem services including medicines and oxygen for humanity both on the PMMs and during semi-structured interviews. The number of students who recognised ecological processes increased from two to five after the visit. These participants described species interaction like pollination, dispersal or habitat provision indicating that the visit increased students' awareness of the ecological roles of species. However, out of 13 students, seven maintained a purely utilitarian perspective adopting a human-centric view.

Table 1. Knowledge scores of students before and after the visit for the ecological literacy lens of biodiversity learning.

Aspects of learning under the 'Ecological literacy' lens		Knowledge score 1	Knowledge score 2	Knowledge score 3
Understanding the concept of biodiversity		Biodiversity is different types of plants and animals. Some examples also include humans and domestic animals	Biodiversity is different types of plants and animals. They have different characteristics either in terms of their mode of reproduction, feeding or body shapes.	Biodiversity is about plants and animals which are different. They have different characteristics either in terms of their mode of reproduction, feeding or body shapes. The plants and animals live in different ecosystems.
Number of students	Before the visit	5	4	4
	After the visit	4	2	7
Understanding of the importance of biodiversity		Student shows little or no awareness of the importance of biodiversity. The student does not mention anything about ecosystem services or ecological processes.	The student shows awareness of ecosystem services provided to humans such as food, shelter, medicines and nutrient recycling.	The student shows awareness of ecosystem services provided to humans such as food, shelter, medicines and nutrient recycling. The student also describes some ecological processes, such as maintaining food webs and nutrient cycles.
Number of students	Before the visit	1	10	2
	After the visit	1	7	5
Understanding of endemic species and extinction		The student does not know about endemic species or extinction.	The student shows an understanding of endemic species or extinction with at least one example.	The student shows an understanding of both endemic species and extinction with at least one example of each
Number of students	Before the visit	2	3	8
	After the visit	1	1	11
Awareness of conservation practices as a means to preserve biodiversity		The student does not show awareness of conservation practices at all.	The student shows awareness that humans are protecting species and ecosystems to protect endangered species with at least one example	The student shows awareness that humans are protecting species providing at least one example. The reason is to prevent extinction and to maintain a balance in ecosystems.
Number of students	Before the visit	6	7	0
	After the visit	2	9	2

Eleven students left IAA with increased understanding of endemic and extinct species elaborating examples of animals encountered during the tour on their PMMs and during interviews. Even though two students could not explain both terms, all participants described species which they linked to their visit experience. These include the red-veined leaves of endemic plants displaying the phenomenon of heterophylly or their hands-on experiences of touching bronze models of extinct animals which struck them due to their astoundingly large sizes. Five students described the changes in the plumage colour of male Mauritian fodies during courtship. Thus, endemic and extinct species stimulated emotional arousal and impressed students which helped them recall detailed information.

The visit permitted most students to increase their knowledge of conservation measures. The elaborated examples during interviews were of captive breeding, tagging and translocation of plants and animals, which were presented during the guided tour. Despite this, only two students could connect the essence of conservation which is meant to prevent extinction and maintain ecosystem balance. Only one student wrote the phrase 'nature reserves prevent extinction' on her PMM, indicating a poor mention of conservation on PMMs.

Biodiversity and society lens

Students were empowered to formulate opinions regarding anthropological activities that destroy ecosystems and the mass culling of bats. Thus, the visit enabled the students to acknowledge the societal influences on biodiversity. However, most students retained their pre-visit conception on the dodo's extinction as shown Table 2. There was no mention of biodiversity and society issues on the PMMs at all.

Nature and self lens

Students' knowledge scores shifted from score 1 towards scores 2 and 3 after the visit as shown in Table 3 below. There was an increased appreciation and engagement with nature with nine students who claimed to also enjoy learning about nature indicating that the visit instilled a desire for further discovery and contributed to a conative dimension of learning (Alsop and Watts 1997). Furthermore, the experience of the nature reserve permitted 10 students to revise their opinions regarding the morality of preserving life, with seven students who advocated for the duty of humans to protect life on purely moral grounds. However, only three participants recognised the importance of preserving life both from an ecocentric and moral perspective.

Before and after the visit, students in the group had different depths of knowledge; some demonstrated limited knowledge. In contrast, others had deeper reasoning and understanding illustrated by their ability to synthesise and analyse different information as shown in this section through the different knowledge scores. Furthermore, a particular student may progress from knowledge score 1 to 2 for one aspect of biodiversity learning but remain the same for another. Therefore, we considered analysing how individual students learnt.

How much did individual students learn?

A mean knowledge score was calculated for each student considering the score they attained for the three lenses before and after the visit. This enabled a comparison of learning gains among students across the group as shown in Figure 2. Students' names are pseudonyms.

Across the group, individuals' mean pre-visit knowledge scores varied widely from a score of 1.1 to 2.4 on a scale of 1 to 3. This indicates a diversity of prior knowledge of biodiversity among the participants in this study. The post-visit knowledge score for each student was higher than his/her pre-visit knowledge score and provides evidence that all students learnt something about biodiversity due to their visit. While certain students learnt more than others the mean increase in knowledge score was irrespective of students' prior knowledge score. For example, both Owen (low prior knowledge score of

Table 2. Knowledge scores of students before and after the visit for the biodiversity and society lens of biodiversity learning.

Learning aspects for 'Biodiversity and society' lens		Knowledge score 1	Knowledge score 2	Knowledge score 3
Awareness of the negative impact of humans in ecosystems		The student does not show an awareness of past and/or current human activities that threatened the environment/ecosystem such as pollution, deforestation, urbanisation	The student demonstrates awareness of human activities that destroy ecosystems and the resulting negative impact on the environment such as reduced forest cover, impact on nutrient recycling or species loss	The student demonstrates awareness of human activities that destroy ecosystems and the resulting negative impact on the environment. Therefore, it is necessary to curtail this to protect ecosystems
Number of students	Before the visit	7	4	2
	After the visit	4	3	6
knowledge on the extinction of the dodo		The student thinks the dodo was a large flightless bird that is 'extinct' or 'disappeared' or 'no longer exists'	The student knows the dodo was a large flightless bird which is extinct as it was killed or hunted by the Dutch and other colonisers	The student knows the dodo is extinct due to the impact of colonisation including hunting, habitat destruction and the spread of invasive species such as rats that predated on eggs.
Number of students	Before the visit	4	9	0
	After the visit	3	7	3
Awareness of debates on the culling of bats		The student is not aware of the debate surrounding bats' culling, describing that the 'bats have the right to life' or students have no opinion.	The student demonstrates an awareness of the on-going discussion surrounding the bats as they cause harm to planters. The student believed that bats should not be killed because they have the right to life or they have important ecological role	The student demonstrates an awareness of the on-going discussion surrounding the bats as they cause harm planters, but they should not be killed because bats have important ecological roles. Mass culling might put the population at stake
Number of students	Before the visit	7	5	1
	After the visit	5	1	7

1.4) and Tom (higher prior knowledge score of 2.4) both had a mean increase in knowledge score of 0.4. Therefore, it is not a norm that students who enter an informal learning setting with higher knowledge will learn more than those at the lower end of the knowledge continuum or vice-versa.

Words and concepts on PMMs

Considering the PMMs, there was a high variability (illustrated by the high standard deviations) in the pre- and post-visit number of words and concepts showing that the prior knowledge and knowledge gain among students differed considerably as shown in Figure 3. For ease of comparison, we plotted the X-axis starting with the student Ryan who had the lowest number of pre-visit words

Table 3. Knowledge scores of students before and after the visit for the nature and self lens of biodiversity learning.

Learning areas for 'nature and self' lens		Knowledge score 1	Knowledge score 2	Knowledge score 3
Appreciate the intrinsic value of natural environments		The student shows little or no appreciation for nature.	The student shows appreciation for nature and experiences nature through activities.	The student shows appreciation, experiences nature and enjoys learning about nature.
Number of students	Before the visit	5	2	6
	After the visit	0	4	9
Learning the ethics of preserving nature/ biodiversity		The student thinks that all life have the moral right to exist or have no opinion about all life forms should exist.	The student shows awareness that all life have the moral right to exists and humans have the moral duty to protect them	If student shows with reasons, an awareness that all life have the moral right to exists and humans have the moral duty to protect them since we depend on balanced ecosystems for the survival of mankind
Number of students	Before the visit	5	8	0
	After the visit	3	7	3

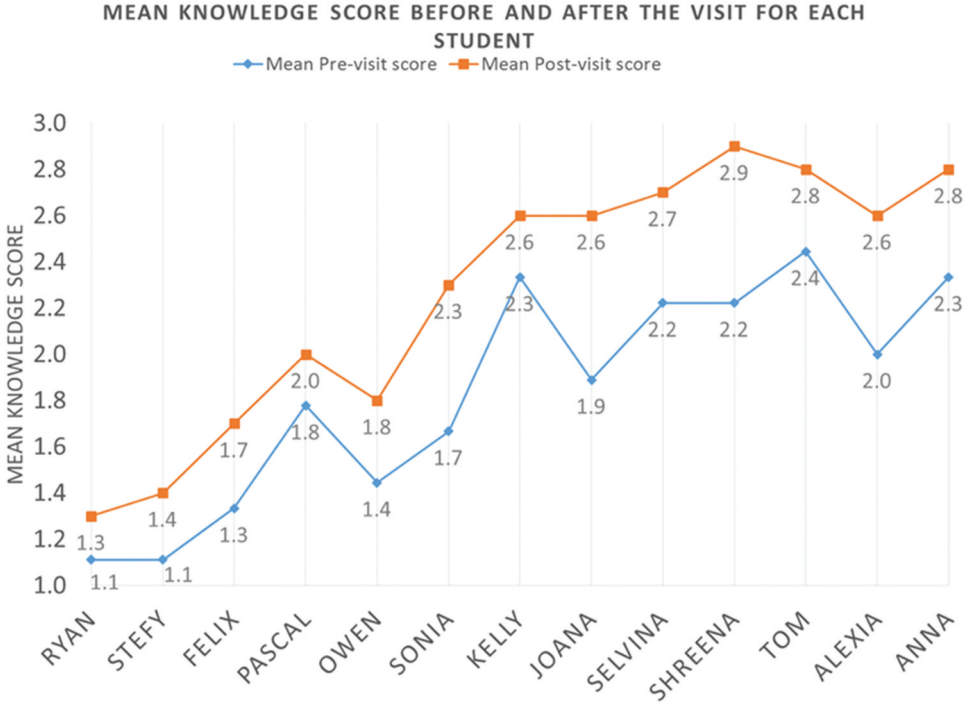
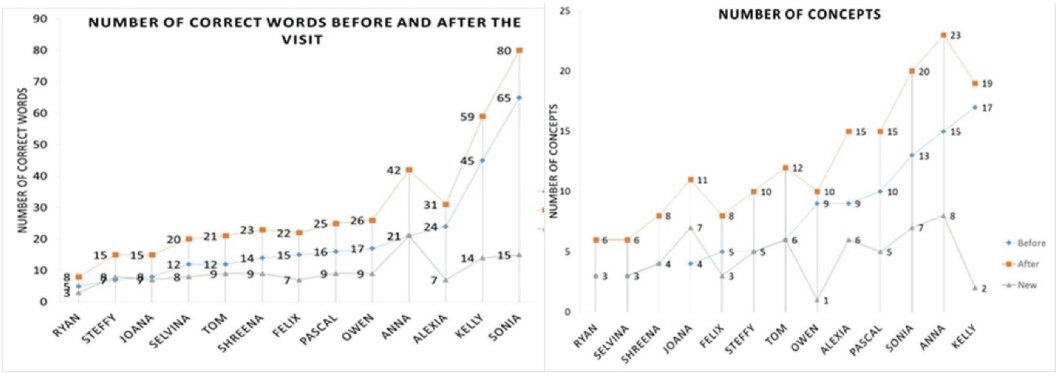


Figure 2. Mean knowledge score for individual students before and after the visit.



	Pre-visit PMMs	Additions in post visit PMMs
Number of Words	Mean: 20.1, std: 16.9	Mean: 9.4, std: 4.8
Number of Concepts	Mean: 7.7, std: 4.5	Mean: 4.4, std: 2.1

Figure 3. Words and concepts written on the PMMs of individual students before and after the visit.

and concepts. The findings reflect that the participants arrived on IAA with different levels of conceptual and vocabulary knowledge which in turn influenced the subsequent additions on the PMMs.

A high number of pre-visit words (above 20) among students (Anna, Kelly and Sonia) corresponded to a higher number of additional words (above ten words) on the PMMs. A low number of correct words pre-visit led to fewer additions (less than 10 words) for students like Ryan, Stefy and Joana. This suggests that word additions after the visit are dependent on prior knowledge. On the contrary, conceptual additions appear independent of the pre-visit concepts, as shown in Figure 3. Students like Anna and Kelly, with similarly high number of pre-visit concepts (more than 10), differed in the number of additions they made Anna had eight additional concepts, while Kelly added only two concepts. Students like Ryan, who had a lower number of pre-visit concepts, made fewer additions, but this observation cannot be generalised. The student Joana is the only student who had more additional concepts in her PMM compared to her pre-visit PMM. The range of additional concepts (from 1 to 8) added by students across the group suggests that conceptual learning differed among students. Overall, all students exhibited an increase in the number of concepts in their post-visit PMM compared to their entry number of concepts, thereby indicating that everyone learnt at least one additional concept.

Short portraits of two students

A short portrait of two students, Owen (low prior knowledge) and Anna (higher prior knowledge), is provided to highlight individual differences in learning. The knowledge scores they achieved for the three lenses of biodiversity learning are presented in Table 4:

Both Owen and Anna are 14-year-olds who attended the trip to IAA. They progressed in knowledge scores for at least one aspect of the three lenses of biodiversity learning. Before the visit they described enjoying watching wild-life documentaries and trekking but after the visit both displayed a willingness to learn more about nature. Owen much impressed by his visit, tried to search for the animals on the internet, while Anna highlighted how much she now 'enjoyed learning about plants and animals', thereby indicating a desire for further discovery. Both progressed from a score of 2 to 3, concerning the 'nature and self' lens of biodiversity learning.

Table 4. Comparison of knowledge scores for two selected students

		Ecological Literacy lens				Nature and Self lens		Biodiversity and Society lens			
		Understanding the concept of biodiversity	Understanding the importance of biodiversity	Knowledge of the terms endemic and extinct	knowledge of conservation practices	appreciation, experience and learning about nature	view on the morality of conserving species	understanding of the negative impact of man on the ecosystem	awareness of the bats' debate	knowledge of the causes of the extinction of the dodo	Mean knowledge score
Owen	Pre-visit score	1	2	3	1	2	2	1	1	1	1.4
	Post-visit score	1	2	3	2	3	2	1	1	2	1.9
Anna	Pre-visit score	3	2	3	2	2	2	3	2	2	2.3
	Post-visit score	3	3	3	2	3	2	3	3	3	2.8

Owen added nine words and only one concept to his PMM (Figure 1). Prior to the visit, Owen's PMM described diversity of living things in terms of plants and animals exemplified through common names of the medicinal plants and animal species. He also included the endemic plant, ebony, explaining the term endemic as 'found only in one country' and illustrated extinct species using the dodo as the only example attaining a score of 3. Following the visit, he explained his PMM as follows: there was a bronze model of an owl which is now extinct from Mauritius (he wrote 'status owl' in his PMM) and he wrote additional examples of endemic animals and plants encountered on IAA. Owen showed a deepening of his existing conceptions of extinct and endemic through his ability to describe new examples encountered on IAA. Despite this, his conceptualisation of biodiversity remained at species level (knowledge score 1), since he did not describe ecosystem diversity at all, nor did he explain the nature of differences among species.

Anna's PMM shows a fair organisation of her ideas, classifying diversity of living things as plants and animals and then expanding on different classes of animals with examples (Figure 4). She made 21 additions of words and eight conceptual additions after the visit, illustrating how she connected her newly learnt materials to her existing conceptions.

Anna specifies both on her PMM and during the interview that 'biodiversity is about humans, plants, and animals that differ in their characteristics and live in different ecosystems (cold and hot regions). She explained that humanity's survival is dependent on many types of ecosystems and species. Therefore, Anna's post-visit knowledge score for understanding the concept of biodiversity remained at 3 and compared to Owen she described diversity at ecosystem level recognising the interrelationship among organisms.

Prior to the visit, Owen was unaware of conservation measures. Following the trip, he described the 'tortoises with numbers on their carapace to identify them' as an example of human intervention to protect species, indicating an awareness of tagging of animals for their identification, thereby progressing from no awareness (knowledge score 1) to an awareness that humans are conserving

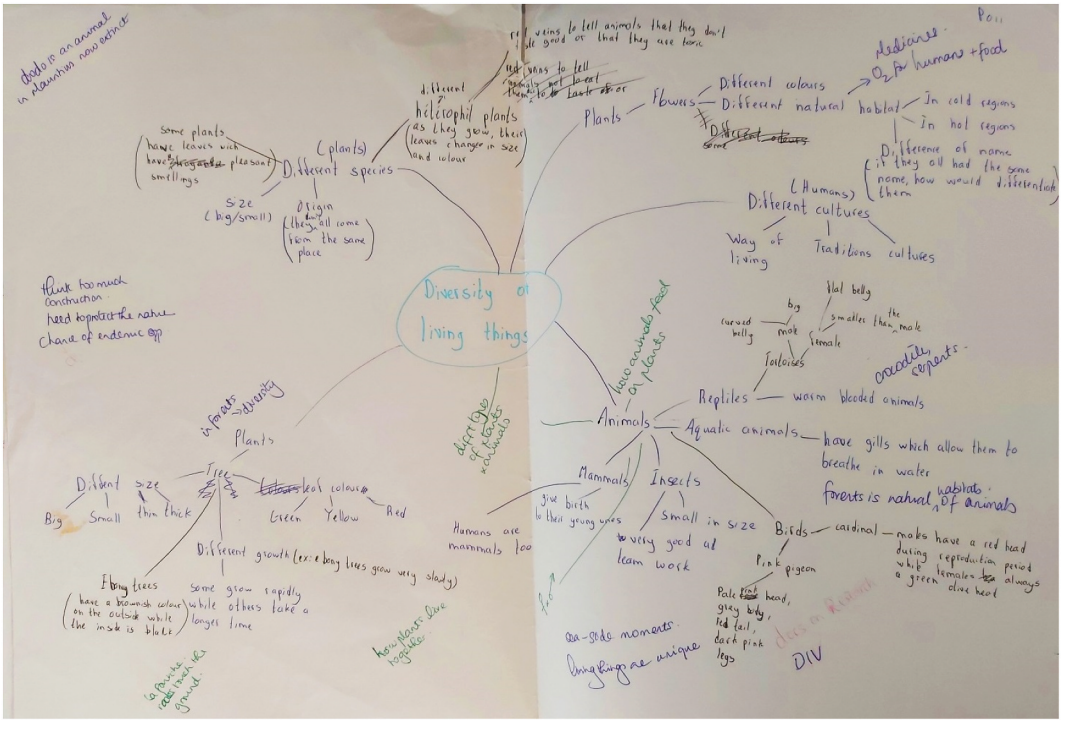


Figure 4. Anna's Personal Meaning Map.

species and ecosystems to protect endangered species with at least one example (knowledge score 2). Anna's awareness of conservation practices before and after the visit remained unchanged with a score of 2 reflecting her idea that 'nature reserves protect species'. Thus, both students could not explain that conservation is meant to curb extinction rates.

The knowledge score of the two students regarding the extinction of the dodo was different; Owen modified his pre-visit description of the dodo as a 'big bird that has gone extinct' and specified during his post-visit interview that the 'Dodo has gone extinct as the Dutch killed them for food', thereby moving from a knowledge score of 1 to 2. After the visit, compared to Owen who limited his understanding of the dodo's extinction to be due to the killing by the Dutch, Anna reviewed her prior conceptions in her post-visit interview. She described that the introduction of predators as well as the dodo's inability to fly, contributed to its extinction, thereby acknowledging the consequences of colonisation on biodiversity. Thus, Anna's knowledge score progressed from 2 to 3.

Before and after the visit, both students showed awareness of pollution and deforestation as negative effects of human activities on the ecosystem. Owen, however, remained at awareness (score 1) but Anna could recognise that such activities threaten endemic species and may lead to species loss, thereby attaining a score of 3. The students' views about bats' culling differed. Owen adopted a moral stance claiming that bats 'have the right to life just like us, human beings' without any indication of the current socio-scientific debates over the mass culling. His knowledge score remained at 1. On the other hand, Anna who was previously aware of the culling (score 2) could formulate opinions backed up by ecological reasoning (score 3), linking the important ecological roles of bats which may become at risk. She explained:

Anna: they might go extinct. Bats form part of our ecosystem, if there are no bats, they will not be there to transport the fruits, there will be no new plants that will grow in Mauritius.

Owen is considered as a student who entered IAA with limited knowledge, managed to learn something about biodiversity but did not make significant knowledge gain. Nevertheless, he deepened his prior knowledge regarding endemic and extinct species, causes of the dodo's extinction, and learnt about conservation practices. Despite having a comparatively high entry knowledge, Anna is an example of a student who seemed to have grasped important details about the exhibits encountered. She started the trip with a certain degree of factual and conceptual knowledge (sometimes like Owen's post-visit knowledge score). After the visit, her prior knowledge was extended, for example, she learnt that predators contributed to the dodo's extinction. Her analytical and evaluation skills seemed enhanced after the trip as she formulated opinions about socio-scientific issues. She recalled detailed explanations from the guide (the male Mauritian Fody changes colours during mating seasons), tied ideas together and linked different concepts (linking urbanisation and deforestation that puts endemic species at risk of extinction). However, Anna could not reason how extinction upsets the balance in ecosystems despite her understanding that biodiversity provides important ecosystem services for humanity. For Anna, who had a comparatively higher prior knowledge than students like Owen, the concept of ecosystem balance appeared blurry.

Discussion

This study investigated what students learn about the concept of biodiversity during a guided nature reserve visit using PMMs. Since biodiversity is a vast concept, we framed our investigation of 'what' students learnt around three lenses: ecological literacy, nature and self and biodiversity and society. First, the results show that a higher number of students deepened their ecological literacy in terms of understanding ecosystem services both from a utilitarian and ecocentric perspective by describing processes of nutrient recycling, pollination, dispersal, and habitats. However, the concept of 'balance in nature' was not clearly revealed by students even those who had higher knowledge scores which is contrary to the findings of Kilinc et al. (2013). Despite this, the latter authors point out that

their Turkish high school participants used the phrase as a metaphor without further reasoning, indicating a possibility that 'balance in nature' might be an abstract concept for this age group. However, an understanding of species interaction and ecological roles is the starting point for a more comprehensive understanding of ecosystem balance and conservation.

Second, the results showed an increased awareness of conservation measures following a trip to IAA. Considering appeals to include conservation in biodiversity curricula (Yli-Panula et al. 2018), educational field trips to nature reserves might be useful supplements to classroom teaching and learning.

Third, the results showed that students had limited prior knowledge of endemic and extinct species from Mauritius and tended to name exotic and domestic animals, like those of Yorek et al. (2008). This result is not surprising considering that less than 2% of the land area of Mauritius is covered with native forests indicating that Mauritian students might not be adequately exposed to native species during their daily interactions. This result confirms the findings of Bermudez, Diaz, and De Longhi (2018), that when asked about biodiversity, students are more likely to name exotic and invasive plants than native ones. Considering that invasive species have destructive effects on native flora and fauna, and that students' knowledge of endemic species increased after the visit, we recommend inclusion of information about both endemic and invasive species and their impact on local biodiversity while discussing conservation during both formal and informal education programmes.

Following the trip to IAA students cited a wider range of endemic and extinct species thereby showing an increase in contextual knowledge of local biological resources. However, providing new examples of species after the visit does not imply a more holistic understanding of the concept of biodiversity as illustrated by the analysis of the PMMs. Most participants restricted their conceptual understanding of biodiversity at species level, overlooking genetic diversity, in accordance with several studies (e.g. Yorek et al. 2008; Menzel and Bögeholz 2009), thereby confirming that students of this age group are challenged to understand the definition of the concept. Yet, a few students could recognise ecosystem diversity following the visit. Field trips to nature reserves could help expand students' comprehension of the concept of biodiversity since field trips are valuable resources for experiential learning (Behrendt and Franklin 2014) and experiencing organisms in natural habitats enhance students' ability to discern biodiversity (Helldén and Helldén 2008).

The results show a deeper comprehension among students regarding biodiversity and society issues compared to their prior knowledge as exemplified by their answers regarding the bat culling issue and the underlying moral and ecological reasons for the conservation of species. Having seen biodiversity conservation in an authentic setting permitted students to increase their appreciation of the intrinsic value of nature. Thus, the visit enabled learners to recognise the historical and socio-cultural embeddedness of science and scientific ideas, as suggested by Pedretti and Nazir (2011).

The results of the study also reveal the individual nature of the learning that occurs in informal spaces as illustrated by the comparison of the two students Anna and Owen. Anna's mean pre-visit score was higher than Owen's mean post-visit score, highlighting how different individuals enter an informal learning experience with varying amounts of prior knowledge, which in turn determines subsequent knowledge gain. However, the increase in knowledge scores for each student was similar indicating a low variation in the amount of new knowledge gained, irrespective of prior knowledge. Furthermore, a particular student does not progress in all aspects of the three lenses of biodiversity learning investigated. Thus, an individual's ability to grasp new information will remain limited and feeding a large amount of detailed information during guided tours does not imply more knowledge gain by visitors. Instead, we invite tour guides to adapt their content delivery to incorporate more questioning, instead of using a purely transmission mode of content delivery. This might cater for the needs of students with different prior knowledge and learning abilities.

In this study, a higher enrichment of biodiversity-related vocabulary was found compared to conceptual additions on the PMM. New words were dependent on pre-visit words for all participants, showing a better comprehension of existing concepts (Rupley et al. 2012). These findings support the idea that visitors are more likely to confirm their pre-existing understandings in informal learning settings than build new knowledge structures (Falk and Dierking 2013, 94). However, the small number of PMMs analysed (13) is a limitation preventing the confirmation of this claim. Students could make conceptual additions despite a low prior knowledge, showing that new conceptual learning is possible during informal learning and is probably also dependent on affective factors such as situational interest and affective learning (Kamudu 2021).

Finally, the study has demonstrated the value of PMMs in investigating prior knowledge and the individual nature of learning, without the pre-conception of what learners should know. When presented with the phrase 'diversity of living things', students' approach of biodiversity was mainly through an 'ecological literacy' lens providing examples of plant and animal species and their importance for humanity. This implies that students do not intuitively connect biodiversity with society issues or write about their personal connectedness with nature. Nevertheless, the post-visit PMMs had more examples of endemic and extinct species illustrating aspects of the visit that captured student's attention. This makes the PMMs promising for practitioners desiring a quick evaluation of their most successful exhibits. The analysis of PMMs can be adapted to suit researchers' needs and research questions (Falk 2003). Hence, we suggest a wider use of PMMs, preferably coupled with other tools such as interviews for deeper investigation of learning.

Conclusion

This study adds to literature on informal learning of biodiversity in developing countries. It has shown that students can learn about biodiversity during a visit to a nature reserve as part of their leisure activities. Investigating the vast concept of 'biodiversity' through the three lenses proposed, might help decode 'what' students learnt about biodiversity. The visit enabled an increase in ecological literacy and individual connectedness with nature among participants. Students' critical skills regarding biodiversity and society issues increased. In addition, this study showed that PMM is an invaluable tool for capturing what students learn, vocabulary enrichment and conceptual additions. Finally, the PMMs enabled us to highlight the idiosyncratic nature of informal learning. It is suggested that tour guides consider prior knowledge of students, scaffolding information instead of using the same script with all visitors.

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